This article has been accepted for publication in JISAKOS following peer review.
The definitive copyedited, typeset version is available online at 10.1136/jisakos

Prioritized challenges in the management of acute knee dislocations are stiffness, obesity, treatment delays, and associated limb threatening injuries.

A global consensus study.

Authors

1. Michael Held
2. Robert C. Schenck Jr
3. Vikas Khanduja
4. Túlio Vinícius de Oliveira Campos
5. Sachin Tapasvi
6. Andrew Williams
7. Wai Pan YAU
8. Christopher Harner
9. Authorship group `Knee surgery in LRS'

Affiliations

[1]Department of Orthopaedic Surgery, Groote Schuur Hospital, Orthopaedic Research Unit, University of Cape Town, South Africa
[2]Department of Orthopaedics & Rehabilitation, The University of New Mexico Health Sciences Center, Albuquerque, New Mexico, United States
[3]Orthopaedic Department, Addenbrooke's Hospital, Cambridge, University of Cambridge, United Kingdom.
[4]Orthopaedic Department, Universidade Federal de Minas Gerais, Belo Horizonte, Brazil
[5]The Orthopaedic Speciality Clinic, 16 Status Chambers, 1221/A Wrangler Paranjpe Road, Pune, 411004, India
[6]Fortius Clinic, London, United Kingdom
[8] Department of Orthopaedics and Traumatology, The University of Hong Kong, China
[8]Department of Orthopaedic Surgery, University of Texas Health Science Center, Houston, USA

Corresponding Author Michael Held. Orthopaedic Research Unit, Division of Orthopaedic Surgery, Groote Schuur Hospital, H49, Old Main Building, 7925 Cape Town, South Africa.
Email: michael.held@uct.ac.za. Telephone: 021 404 5108.

Keywords
Knee dislocation, multiligament knee injuries, consensus study, challenges, stiffness, vascular injuries, obesity, treatment delays

ORCID iDs
M. Held: 0000-0002-0671-0439
R. C. Schenck Jr: 0000-0001-5292-7017
V. Khanduja: 0000-0001-9454-3978
A. Williams: 0000-0001-6756-2751

Funding There is no funding source.

Conflict of Interest Andy Williams receives research funding and part-funding of a clinical fellow from Smith and Nephew. He is a shareholder and board member of Fortius Clinic, London and Innovate Orthopaedics. He owns shares in DocComs, a digital start-up providing a secure platform for medics to exchange patient information.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee (HREC 591/2018) and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent This study was approved by the local review board. Informed consent was obtained prior to participation.

Word count: main text: 2798. Abstract: 296

Contributor ship statement
All authors listed have made substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work. They also participated in drafting the work or revising it critically and provided final approval and agreed to be accountable for all aspects of the work to be published. Contributors in the Authorship group 'Knee surgery in LRS' were participating investigators.

Authorship group: Knee Surgery in LRS
Hasan Alizayagam, Carlos Mourao, Diogo Mesquita, Soliudeen Arojuraye, Ednei Freitas, Rtesh Patel, S Deepak, Fernanda Nahas, Paulo Fontes, Gabriel M Miura, Gian Du Preez, Guilherme F Simoes, Leandro Marinho, Roberto Cunha Luciano, Yogesh Gowda, Bernardo Ribeiro, David North, Constantino Calapodopulos Jr, Dustin Richter, Ennio Coutinho, Weili Fu, Frederico Ferreira, Clauco Passos, Hannes Jonker, Hayden Hobbs, John Grant, Sebastian Magobotha, Marcos Alves, Marcelo Amorim, Marcelo Denaro, Marc Safran, Marcelo Moraes, Dinshaw Pardiwala, Rodrigo Lazzarini, Seth Sherman, Saseendar Shanmugasundaram, Sundararajan Silvampatti, Richard von Bormann, Wagner Lemos, Jose M Juliano Eustaquio, Peter Venter

Abstract

Objectives Heterogeneous patient factors and injury mechanisms result in great variety of injury patterns encountered in knee dislocations (KD). Attempts to improve outcome can focus on a wide range of challenges. The aim of this study was to establish and prioritize a list of challenges encountered when treating patients with acute knee dislocations.

Methods A modified Delphi consensus study was conducted with international knee specialists who generated a prioritized list of challenges. Selected priorities were limited to half of the possible items. Agreement of more than 70% was defined as consensus on each of these items a priory.

Results Ninety-one international surgeons participated in the first round. The majority worked in public hospitals and treated patients from low- and middle-income households. Their propositions were prioritized by 27 knee surgeons from Europe, Africa, Asia, as well as North and South America with a mean of 15.3 years of experience in knee surgery (SD 17.8). Consensus was reached for post-operative stiffness, obesity, delay to presentation, and associated common peroneal nerve injuries. Challenges such as vascular injuries, ipsilateral fractures, open injuries, as well as residual laxity were also rated high. Most of these topics with high priority *are key during the initial management* of a patient with knee dislocations*, at presentation*. Topics with lower priority were post-surgical challenges, such as patient insight, expectations and compliance, rehabilitation program, and pain management.

Conclusion This consensus study has a wide geographic footprint of experts around the world practicing in various settings. These participants prioritized stiffness, obesity, treatment delays, and associated limb threatening injuries as the most important challenges when managing a patient with

acute KD. This list calls for applicable and feasible solutions for these challenges in a global setting. It should be used to prioritize research efforts and discuss treatment guidelines.

Level of evidence: V

What are the new findings?

A prioritized list of the most important challenges in the management of acute knee dislocations was established through a modified Delphi consensus study.

A global perspective of international knee surgeons was generated, who mostly worked in public sector hospitals treating patients from middle- and low-income households.

Consensus was reached for post-operative stiffness, obesity, delay to presentation, and associated common peroneal nerve injuries.

Introduction

A knee dislocation (KD) is often defined as complete tibiofemoral articular displacement, although spontaneous reduction or cruciate-intact KDs [1] can add complexity to this definition. Schenck's classification [2] is based on the number of ruptured ligaments and provides more anatomic detail. Most agree that a true knee dislocation commonly leads to disruption of three or more of the main stabilizing ligaments (KDIII).[3] Great variety in injury mechanisms, pattern of associated injuries, as well as unique patient characteristics make KD complex injuries to treat and study.[2] Additionally, most reports are low-level case series with limited power.[4] For these reasons, surgeons are faced with unique challenges when treating KD which vary significantly according to specific hospital settings and availability of resources. Areas with a high trauma burden are often under-resourced with funding, lack of operating time, staff, and skills. As a result the management of KDs differs when comparing high-volume centers in developed countries to other centers with resource limitations.[5, 6] Understanding these challenges is the first step to establish research priorities and

clinical guidelines with global impact. Recent work of leading centers in the USA and Europe has provided solutions to some of these challenges but these might not be transferrable to various socioeconomic settings and hospital setups in other countries. The key to improve the management of KD in these deprived areas is to understand the main challenges presented by KD which need attention regardless of where in the world the patient is being treated.

The aim of this study was therefore to establish and prioritize the most important challenges surgeons from around the world face when managing acute KDs. The emphasis was put on a wide geographic and sectorial footprint of participating surgeons to allow insights into various hospital settings and socioeconomic circumstances.

Methods

A modified Delphi consensus study in form of interactive iterative rounds of communication was conducted[7-9] to prioritize items by international knee experts between December 2019 and February 2020. First a list of items was established which was then prioritized in subsequent rounds by experts who could choose a maximum of 50% of the items that were listed. Consensus was defined as a percentage agreement of 70% of all participants.

Participants

An invitation to possible participants was sent out via email. For the first round the directory of the International Society of Orthopaedic Surgery and Traumatology was used and orthopedic surgeons with a special interest in knee dislocations were targeted. The experts of the second and third rounds were selected based on their experience or the volume of KDs in their practice. They reported to treated at least ten knee dislocations per year and/or had at least ten years of experience in knee surgery. These experts were from Brazil, India, China, South Africa, the United States and the United Kingdom. This provided insight in clinical settings of various countries, cultures and socioeconomic circumstances.

Iterations and timing

During the first-round participants provided specific challenges they faced in the management of acute KD which was submitted as free text answers. Responses were synthetized into categories by the main investigators (all specialist knee surgeons) without access to specific names or affiliation of participants. The established list of challenges was then sent out to the group of experienced knee surgeons for prioritization. This strategy ensured that surgeons with various levels of skills and experience could inform the list of challenges, which could then be prioritized by experienced, high-volume knee surgeons. For the first and second round, participants were blinded to each other's responses. For the third round, the items where prioritized according to their percentage agreement and this information was then shared with the experts prior to their re-prioritization of each challenge item. The entire consensus process was carried out anonymously over a period of three months, with weekly reminders and a four-week period between rounds.[10] The data collection was done electronically using REDCap (Research Electronic Data Capture) electronic data capture tools hosted at the main study institution. This is a secure, web-based application designed to support data capture for research studies with previously documented ease of use and applicability.[11]

Data analysis

Descriptive statistics was used to analyze the consensus agreement. To describe the study population, normally distributed continuous data was summarized by mean, standard deviations (SD) and 95% confidence intervals. Continuous data not distributed normally was summarized by median and interquartile range (IQR). Categorical data was summarized as proportions with 95% confidence intervals. According to the Delphi process, agreement was defined as percentage agreement of ≥70%.

Sample size

Sample size calculations are not routinely performed for Delphi studies. A number from 10-15 of experts is acceptable,[10, 12] although most consensus studies use 15 to 20 participants[13] and usually have a maximum of 50.[14] For the our study a number of 20-30 participants was targeted for each round. Informed consent was obtained prior to participation and the study was approved by the local review board with the number HREC 591/2018. Data are available upon reasonable request.

Results

Participants

Ninety-one surgeons (86 male, 94.5%) with a mean age of 47.3 years (SD 12.5) participated in the first round to establish a list of the most important challenges in the management of KDs. They reported an average of 15 years (SD11.1) of experience. 35 surgeons (38%) were from Asia, 21 (23%) from Africa, 23 (25%) from Europe, and 5 each from North and South America. 53 (58%) worked in public hospitals and 82 (90%) treated patients from low-and middle-income households (Figure 1). These surgeons performed a median of 50 anterior cruciate ligament (ACL) reconstructions (IOR 80) and 6 surgeries for MLKIs per year (IQR 14).

The answers to the open questions of this first round were then prioritized by 27 (100% male) experienced high-volume surgeons in the second and third rounds. These surgeons had a mean age of 46 (SD 8.4) years and a mean of 15.3 years of experience in knee surgery (SD 17.8). All had access to arthroscopic equipment and 24 (89%) had access to magnetic resonance imaging. In this group, 9 (33.3%) were from Brazil, 6 (22.2%), from the USA, 4 (14.8%) from South Africa and India respectively, and 2 (7.4%) each from China and the United Kingdom (Figure). These surgeons reported to perform a median of 80 (IQR 60) ACL reconstructions and a median of 15 (IQR 17.5) surgeries for knee dislocations per year. 18 surgeons (67%**)** worked in public sector hospitals and 24 (89%) treated patients from low- or middle-income households (Figure 2).

List of challenges in the management of KD

The group of experts reached consensus for most important challenges such as post-operative stiffness, obesity, delay to presentation, and associated common peroneal nerve injuries (Table 1). Challenges such as vascular injuries, ipsilateral fractures, and open injuries also reached a high percentage agreement although not enough for consensus as per our definition. Less than 20% of participants prioritized challenges in areas like pain management, access to Magnetic Resonance Imaging (MRI), surgical skills training, sequence of graft tensioning, lack of operating time and the decision making surrounding single stage bi-cruciate reconstruction. Many of the listed challenges are interrelated which should be taken into account especially for items with lower percentage agreement. Notably, some of these challenges need to be addressed outside of the operating room, such as patient insight, compliance and expectations, access to high quality physiotherapy, and pain management. Most of these topics with high priority are key during the initial management of a patient with knee dislocations, at presentation. Topics with lower priority were post-surgical challenges, such as patient insight, expectations and compliance, rehabilitation program, and pain management.

Discussion

This consensus study spans various health care sectors and has a geographic footprint including most major continents with strong participation from Africa, Asia and South America. These surgeons established a list of challenges they encounter in the management of acute KDs and reached consensus of 70% agreement on post-operative stiffness, obesity, delay to presentation and associated common peroneal nerve injuries.

Participants

Of the final round participants, 89% treated patients from either middle - (63%) or low-income (25.9%) households and 67% worked in public hospitals. This provided a global perspective of challenges seen specifically in these settings. Although all participants of the final rounds were

subspecialists, 41.8% of the initial round were general orthopedic surgeons. Specialists are rare in areas with limited resources [15] and the treatment of complex injuries has to be undertaken by generalists.[16] This also influences the challenges posed in patients in these areas of the world with KDs. The inclusion of such surgeons is crucial to identify the specific problems they face and so develop appropriate solutions for these areas. Furthermore, most of these participating surgeons worked in low- to middle-income nations such as South Africa, India and Brazil, which are amongst the countries with the highest trauma burden world-wide.[17] This study is therefore informed by surgeons who have insight into the challenges of high volume trauma in low-resource settings. This can hopefully be translated to other countries with similar circumstances who were not part of this study and for whom studies from developed countries may well not be as relevant.

Priority of challenges

From the list of challenges generated, consensus was reached for postoperative stiffness, obesity, delay to treatment, and associated common peroneal nerve injuries. The following section discusses these four challenges in the light of a global setting with resource limitations.

Postoperative stiffness is a common sequalae after KDs which has been associated with early surgery.[18] Therefore, delaying, or staging, surgery can potentially reduce stiffness but patient selection for delayed or non-operative management can be challenging which was also a point established in our study. One of the most important factors to avoid stiffness is early functional rehabilitation, even though in 10% of patients further surgery for arthrofibrosis is still required.[19] Stiffness also been associated with the extent of the ligamentous injury. [20] Ongoing research is therefore targeting some questions around postoperative rehabilitation. [21] But adequate access to physiotherapy is a further challenge in low-resource settings which was listed in our study. In addition, poor patient compliance and insight can further hamper postoperative recovery. The approach to avoid stiffness for many surgeons in similar circumstances might involve patient

education and improving access to physiotherapy, along with a lower threshold for delayed or staged surgery or even conservative management.

Obesity in KD is another universal challenge as it is associated with significant morbidity. In these patients, surgery can be complicated by iatrogenic neurovascular damage, surgical site infection, or overall poor patient reported outcomes.[22] Difficult postoperative patient mobilization and inability to immobilize the often cone-shaped limb add to the complexity. Consequently, patient expectation must be managed before surgery, explaining risk and benefits.

Delay to treatment is especially common in areas with limited access to health care and long distances to travel to hospitals. In the acute setting with associated vascular injuries, delay to treatment of more than 6 hours increases the risk for limb loss and can be fatal, due to muscle necrosis and reperfusion injury. [23-26] But even without vascular damage, delay to treatment can limit the success of early repair of ligamentous and meniscal injuries, necessitating more complex and costly reconstruction procedures. In severe cases, neglected KD with a permanently fixed dislocated joint often requiring salvage procedures such as arthroplasty or arthrodesis to achieve acceptable function. [6] Education and training of the front-line health care workers, such as nurses, interns and medical officers is a first step to achieve early referral and reduce delays.

Common peroneal nerve injuries are present in up to 40% of KD, especially in posterolateral corner injuries [26-28] and especially so with biceps tendon avulsions, with or without fibular head fractures.[29] With a recovery rate of 25%, [27] nerve repair, grafting, or nerve transfer have been proposed in acute injuries with nerve discontinuity, or later for intact nerves without recovery,[30] but tendon transfers are still the most reliable and feasible surgical treatment [31, 32], especially in the low-resource setting and in delayed cases.

Although consensus was not reached for some items, these remain high in the rating of the participants. **Vascular injuries** (percentage agreement: 67%) were selected as an important challenge as they are reported to occur in on average 18% of cases[33] and are the most time-

sensitive associated injuries in KDs. [24, 25, Rihn, 2004 #144, 34, 35] Selective angiography triggered by an abnormal ankle-brachial index, is often promoted to exclude vascular injuries,[35] but a limited number of health care workers or inadequate training of ward staff can make serial neurovascular checks an unsafe strategy.[36] CT angiography, although highly sensitive and specific, might not always be available. Furthermore, in case of arterial damage, vascular surgery and immobilization via an external fixation device add to the morbidity of the patients especially due to stiffness and pin site complications. Subsequent ligament surgery after recovery can compromise important collateral perfusion and potentially has a higher risk of surgical site infection and stiffness due to the previous surgery.

Another important challenge rated high were **ipsilateral fractures** (percentage agreement: 63%), which occur in 1*6.*6% of knee dislocations.[37] Furthermore, 30% of patients with long bone fractures are reported to present with ipsilateral knee ligament injuries[38] These ligament injuries have increased morbidity,[39] yet, are often overlooked in the presence of fractures. This warrants a thorough clinical examination, especially in the present of knee hemarthrosis, and should ideally be confirmed with a preoperative MRI scan. The coordination of ligamentous surgery at the time of fracture fixation is a major challenge, especially in low-resource settings and procedures are therefore often staged to allow healing of surgical wounds, increase of range of motion, fracture union, and acceptable mobilization. Further challenges arise with intra- or extramedullary fracture fixation devices which can reduce image quality of later MRI scans and might need to be removed to achieve appropriate bone tunnels for reconstruction. In such cases, fracture union is a prerequisite for removal of fixation devices which may delay ligament surgery for several months.

Similarly, **open dislocations** can be devastating injuries and many surgeons rated this challenge highly (percentage agreement: 63%). Skin and soft tissue integument injuries are found in 13% of KDs [40] and are associated with an infection in up to 40% [41, 42]. Adequate irrigation and debridement are paramount, and in most cases stabilization with a knee spanning external fixator is needed. Ligamentous structures should be addressed once soft tissues allow and wounds are healed to

reduce infection risk. This often leads to long delays as pin sites need to heal and range of motion needs to be regained after removal of external fixation.

Limitations

This study has some limitations. Most participants were subspecialist knee surgeons from high volume centers which might have overshadowed the perspective of generalists, thereby creating bias away from the view of those surgeons from less developed parts of the world. However, a large proportion of generalist orthopedic surgeons were included in the first round to reduce this. Also, although a wide range of countries participated, many nations were not represented. Yet, the study findings are still applicable to countries in similar socioeconomic and political circumstances. Furthermore, consensus was reached only for a few challenges in the management of KD although increasing the limit for possible answers to more than 50% most likely would have increased the percentage agreement. Some details from the propositions of the initial round were also lost after categorization into broader topics. Furthermore, consensus was only reached for four items. This would reduce to only two items if the limit of agreement was set to 75% as is often the case for consensus studies. But increasing the limit of possible answers to more than the set value of 50%, would have likely increased the consensus per item. Also, aside from consensus, the main value of this list is its prioritization of challenges. Furthermore, 94.5% of participants in the first round and all participants in the second round were male. This is a reflection of the gender imbalance in Orthopaedic surgery and must lead to mentoring women Orthopaedic surgeons to treat these injuries.

Conclusion

This study provides a prioritized list of challenges in KD which were based on insights of an international group of knee surgeons from Europe, Africa, Asia, North and South America. Consensus was reached for four challenges: post-operative stiffness, obesity, delay to presentation,

and common peroneal nerve injuries. Associated injuries to ipsilateral vessels, long bones and skin were also prioritized with high agreement but did not reach the consensus threshold of 70%. This study can therefore be used to establish and prioritize focused research questions within each of the top challenges, which are applicable to a global setting. It can also serve as basis to discuss treatment guidelines keeping in mind regional variations in health care provision. Overall the study highlights the need for global solutions to address acute knee dislocations.

Figure Legends

Figure 1.

Geographic distribution of participants for the first round shows strong participation from Asia, Africa, and Africa.

Figure 2.

Geographic distribution of the 27 participants of the final round per country.

Tables

Table 1. Challenges in the management of acute knee dislocations as prioritized by the 27 participants of the final round. N=number of participants. %=percentage agreement. The horizontal line indicates the limit of agreement set at 70%.

Challenges in the management of acute knee dislocations	N	%
Post-operative Stiffness	22	81%
Obesity	22	81%
Delay to presentation	20	74%
Associated Common Peroneal Nerve injury	19	70%
Associated Vascular injuries	18	67%
Associated Ipsilateral fractures (extra-articular)	17	63%
Open injuries (periarticular wounds)	17	63%
Post-operative residual instability	17	63%
Patient compliance to post-operative management	16	59%
Managing patient expectations regarding outcome	16	59%
Convergence of tunnels during surgery	15	56%
Allograft limitations (availability and quality)	14	52%
Patient insight into treatment, rehabilitation & expected outcome	13	48%
Decision making: Two stage versus Single stage surgery	13	48%
Osteotomies in multiligament knee injuries	11	41%
Bilateral knee dislocations	11	41%
Objective diagnosis of posterolateral corner injuries	10	37%
Decision making: Repair versus Reconstruction	10	37%
Decision making: Timing of surgery	7	26%
Rehabilitation program (access/adequacy)	7	26%
External fixation (deciding on indications)	7	26%
Associated Meniscal injuries	7	26%
Decision making: Prioritization of ligaments in staged reconstruction	7	26%
Patient selection for conservative management	6	22%
Pain management (pre-and post-operative)	5	19%
Lack of Magnetic Resonance Imaging	4	15%
Surgical skills training	4	15%
Decision making: sequence of graft tensioning	4	15%
Lack of operating time	2	7%
Decision making: Single stage bi-cruciate reconstruction	1	4%

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